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TECHNICAL INFORMATION MEMORANDUM NR. 9

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THE USE OF INSECT REPELLENTS ON CLOTHING

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THE ARMED FORCES PEST CONTROL BOARD

1 JUNE 1961

The basic material upon which this Technical Information Memorandum is based was prepared by Dr. Carroll Smith and the staff of the Orlando Laboratory, Division of Insects Affecting Man and Animals, Agricultural Research Service, U. S. Department of Agriculture.

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1. PURPOSE

Repellents have been developed to protect the individual from biting arthropods which transmit diseases and cause severe annoyance. Repellents are used either by direct application to the skin or by treatment of clothing. The purpose of this memorandum is to present the methods and materials used, particularly for the treatment of clothing.

2. REPELLENTS

a. GENERAL

Repellents may be used effectively to provide protection from four principal groups of arthropods: mosquitoes and other biting Diptera; ticks; fleas; and chiggers. Land leeches are a problem in some areas, and repellents may be used to provide protection. Depending upon the species, it may be necessary to apply the repellents to the skin, to the clothing, or to both skin and clothing. Mosquitoes and some other Diptera bite either the exposed skin or through light-weight clothing, and both types of treatments are necessary to provide complete protection. Black flies and fleas may crawl under the clothing to bite, or may bite on the exposed skin, and again both types of treatments are required. One should never depend on clothing treatments alone to protect against the pests that bite the exposed skin, as the present repellents do not have a wide enough field of action to affect arthropods more than a few centimeters from the treated surface. Clothing applications alone ordinarily provide protection against ticks and chiggers. When wearing heavy clothing, a repellent applied to the exposed skin alone may provide adequate protection from mosquitoes and some other Diptera.

Most of the repellents have a slight odor; this is usually unobjectionable but is more pronounced with M-1960 than with the other materials. Plastics such as watch crystals, fountain pens and pocket combs may be damaged by contact with the freshly-treated clothing or the repellents. Deet is less injurious than M-1960 or benzyl benzoate. Some types of synthetic cloth, such as the older types of rayons, may be affected but no injury is caused to nylon, cotton, or wool, and the repellents do not stain or change the appearance of the present types of uniforms.

No one repellent has been found to provide the very best protection against all groups of arthropods. Effectiveness of the commonly used individual compounds and mixtures is indicated in Table 1.

The common names, catalogue nomenclature, applicable specifications and Federal stock numbers for repellents in the military supply system are listed in Table 2.

b. INDIVIDUAL COMPOUNDS

Deet (N,N-diethyl-m-toluamide) provides the best protection against all types of mosquitoes and other biting Diptera, and is safe for application to the skin as well as the clothing. Butyl ethyl propanediol, an ingredient of mixture M-1960, is almost equal to deet as a clothing treatment against mosquitoes, but is not cleared for application to the skin. Ethyl hexanediol, dimethyl carbate, Indalone, and dimethyl phthalate are older repellents that have been used primarily for skin applications for protection from mosquitoes; they will also provide protection against mosquitoes when applied to the clothing, but are less effective than deet or butyl ethyl propanediol.

The most effective material for protection against ticks is N-butylacetanilide, and this is also an ingredient of mixture M-1960. It is not deemed safe for use on the skin. Among the other materials which are likely to be readily available, the most effective ones for use against ticks, in order of preference, are deet, Indalone, dimethyl carbate, dimethyl phthalate, and benzyl benzoate.

The most effective flea repellent is deet, and this is safe for use on the skin as well as the clothing. Benzyl benzoate and N-butylacetanilide are also highly effective as flea repellents, and both are present in mixture M-1960. Benzyl benzoate is cleared for skin application ONLY AS A SCABICIDE.

Any of the materials mentioned above will provide protection against chiggers when freshly applied, and some are effective through considerable periods of wear. Only benzyl benzoate will withstand leaching by water, however, and for this reason it is considered to be the most effective chigger toxicant (against chiggers the effectiveness is correlated with knockdown activity rather than with repellency). Benzyl benzoate is an ingredient of mixture M-1960, and the mixture therefore withstands some leaching by water, such as would occur if the treated clothing were worn in the rain or while fording a stream. Treated uniforms may still provide protection from chiggers even after 1 or 2 washings, if there has not been too much leaching during the period of wear. The best procedure, however, is to reimpregnate the clothing after every washing. Dibutyl phthalate is also effective as a chigger toxicant; it was formerly used much more extensively than at present, but may be encountered in stockpiled materials, particularly in a mixture with benzyl benzoate.

TABLE 1. EFFECTIVENESS OF REPELLENTS

Repellent	Effectiveness Against:- Mosquitoes	Other Biting Diptera	Ticks	Fleas	Chiggers	Approved for use on skin	Comment
Single repellents							
Benzyl benzoate	--	--	x	xxx	xxxx	only as scabicide	Withstands leaching; 1 or 2 washings, strong placticizer
Butyl ethyl propanediol	xxx	xxx	xx	--	--	No	Solid at normal air temp., crystallizes from solutions at low temp.
Deet (diethyltoluamide)	xxxx	xxxx	xxx	xxxx	xxx[a]	Yes	Effective against land leeches in Malaya
Dibutyl phthalate	--	--	--	--	xxx[a]	No	--
Dimethyl carbate	xx	xx	xx	--	xx[a]	Yes	Solid at low air temp.
Dimethyl phthalate	xx	xx	x	--	xx[a]	Yes	Strong plasticizer
Ethyl hexanediol	xx	xx	--	--	xx[a]	Yes	Least plasticizing action
Indalone	xx	xx	xxx	--	--	Yes	Strong odor
N-butylacetanilide	x	--	xxxx	xxx	xxx[a]	No	Strong odor, placticizer
Mixtures							
Benzyl benzoate -- dibutyl phthalate	--	--	x	x	xxxx	No	Strong plasticizer
M-1960	xxx	xxx	xxxx	xxx	xxx	No	Effective against land leeches in Malaya
M-250 (6-2-2)	xx	xx	x	--	xx[a]	Yes	--
M-2020	xx	xx	x	--	xx[a]	Yes	--

xxxx Best available
xxx Highly effective
xx Moderately effective
x Slightly effective
- Not effective

a/ Will not withstand leaching

TABLE 2. REPELLENTS AVAILABLE IN MILITARY SUPPLY SYSTEM

Nomenclature	Stock Number	Specification	Container	Remarks
Insect repellent, clothing application (formula M-1960)	6840-270-6200	MIL-R-12123	1 gal. can	Available from Army, Navy, Air Force
Insect repellent, personal application (formula 2020)	6840-290-5027 6840-597-2319	MIL-R-249, Type I	2 oz. glass bottle	Available from Army, Navy Available from Air Force
Insect repellent, personal application (75% diethyl-toluamide)	6840-753-4963	O-R-225, Type IIA	2 oz. polyethylene bottle	To replace 6840-290-5027 (formula 2020). Will be available from Army, Navy
	6840-656-1630		2 oz. bottle	Air Force
Insect repellent, clothing application (90% benzyl benzoate)	6840-281-2062	MIL-I-51022 (CmlC) Grade B	1 gal. can	Available from Army
Insect repellent, clothing application (45% benzyl benzoate, 45% dibutyl phthalate)	6840-246-6435	MIL-I-51022 (CmlC) Grade A	1 gal. can	Available from Army until present supplies are exhausted
Insect repellent, personal application (formula 6-2-2)	6840-396-1013		3 oz. can	Available from Air Force

Both M-1960 and deet have been reported as effective against land leeches in Malaya.

c. MIXTURES

Mixture M-1960 was developed to meet the requirements for an all-purpose clothing repellent. It contains 30% of 2-butyl-2-ethyl-1, 3-propanediol for protection against mosquitoes and biting flies, 30% of benzyl benzoate for chiggers and fleas, 30% of N-butylacetanilide for ticks and fleas, and 10% of a nonionic emulsifier.

Benzyl benzoate, either alone or mixed with dibutyl phthalate, is available in emulsifiable formulations designed primarily for the treatment of clothing for protection from chiggers. The treatments will also provide protection against fleas, but not against mosquitoes and little against ticks. One formula contains 90% of benzyl benzoate as the toxicant and repellent, and another formula contains 45% each of benzyl benzoate and dibutyl phthalate. Each formulation contains 10% of a nonionic emulsifier.

Mixture M-2020 contains 40% of dimethyl phthalate, 30% of dimethyl carbate and 30% of ethyl hexanediol, and mixture M-250 (6-2-2) contains 60% of dimethyl phthalate, 20% of Indalone and 20% of ethyl hexanediol. These mixtures antedated deet as the recommended repellent for skin application. They may remain in supply channels for some time, and can be used as an expedient to treat clothing for protection from mosquitoes, biting flies, chiggers, and ticks. They are not available in emulsifiable concentrates.

d. APPLICATION RATES

The optimum rate of application for each of the individual repellents to clothing is 2 grams per square foot, or a total of about 2½ ounces to a uniform of average size, including a pair of socks. The optimum rate for M-1960 and the benzyl benzoate-dibutyl phthalate mixture is 1 gram of each active ingredient per square foot. For this reason the total application rate for M-1960 is greater than that of the other repellents. Since three active ingredients are required to provide protection against the entire range of pests, it is necessary to apply the mixture at a rate of 3 grams per square foot.

The directions given in this memorandum are based on depositing the repellents at these rates, and they should be followed exactly. Methods of treatment with emulsifiable concentrates that are satisfactory for cotton may not always be satisfactory for wool, and wet uniforms are more difficult to impregnate at prescribed rates than are dry ones. Any attempt to modify the methods, unless supported by chemical analyses of the deposits obtained, may be disastrous, resulting in failure to obtain protection or the application of excessive amounts of the repellents which could be harmful to the wearer.

3. METHODS OF TREATMENT

a. WITH EMULSIFIABLE CONCENTRATES

(1) Impregnation in Laundries

Repellents are easily applied in fixed or mobile laundries, and this method is preferred for treatment of large amounts of clothing. The following table gives the recommended dosages and drying temperatures:

Formula	Type of cloth	Amount of concentrate	Number of Uniforms	Drying temperature
M-1960	Cotton	6 quarts	20	200°F
Benzyl benzoate[1/]	Cotton	7 pints	20	200°F
M-1960	Wool	3 quarts	14	140°F
Benzyl benzoate[1/]	Wool	3.5 pints	14	140°F

1/ The methods recommended for benzyl benzoate here and in the following paragraphs also apply to the benzyl benzoate-dibutyl phthalate mixture.

(a) Cotton Clothing. -- After the last rinse or after clean clothing is thoroughly wet, drain the washer and roll for 2 minutes to remove excess water from the uniforms and to insure complete drainage of the reservoir. For lots of 20 uniforms, add 4 gallons of water (100°F), start the washer, add 6 quarts of M-1960 concentrate, or 7 pints of benzyl benzoate concentrate, and roll for 10 minutes. Drain the washer as previously described and remove clothing for drying. Spin dry for 3 minutes at 1,600 r.p.m., and tumble dry for 10 minutes at 200°F.

(b) Wool Clothing. -- The process for treating woolens is as given for cotton clothing, with the exception that 3 quarts of M-1960 concentrate or 3.5 pints of benzyl benzoate concentrate are used to 4 gallons of water heated to 100°F., for 60 pounds of clothing, dry weight (14 shirts and 14 trousers or 7 blankets). Drying should be at temperatures below 140°F.

(2) Hand Treatment

(a) Dry Uniforms. -- This procedure is for clean, dry clothing of wool or cotton and is the one which should be used for treating small quantities of clothing or if laundry facilities are not available. A stock emulsion is prepared by adding the required amount of repellent concentrate to the required amount of water as given in the following table:

Formula	For stock emulsion: Amount of concentrate	For stock emulsion: Amount of water	Amount of stock emulsion per uniform	Number of uniforms
M-1960	1 gallon	11 gallons	3.5 pints	28
	4.5 oz (130ml. or 9 tablespoons)	3.5 pints	3.5 pints	1
Benzyl benzoate	1 gallon	18 gallons	3.5 pints	43
	2.5 oz (72ml. or 5 tablespoons)	3.5 pints	3.5 pints	1

The stock emulsion should be stirred occasionally to maintain the emulsion (milky white). One to three dry cotton or wool uniforms (shirt or jacket, pants, and socks) are placed in a flat container. While one man slowly pours the required amount of emulsion on the clothing, another man should turn and squeeze the cloth to insure even and complete wetting. To remove the excess emulsion, the clothing should be wrung by two men. Men treating more than two or three uniforms should wear rubber gloves. The emulsion that is not absorbed by the uniforms must not be used again. The uniforms should be laid out flat on a clean dry surface to dry, if possible, rather than hung on a line. When flat drying is impractical and suspension drying must be employed, the trousers should be hung with the bottoms of the legs down and the shirts with the neck and sleeves down. When the suits are dry they are ready for wear. If there is to be a delay of several days they should be folded compactly and stored indoors.

(b) Wet Uniforms. — This method should be used only as an expedient, when the only opportunity to treat the clothing is during the short period after it has been washed and before it can be dried. After treatment, uniforms must be dried before they are worn. After the uniforms have been washed and rinsed two men should wring out by hand as much excess water as possible. Then, with one man slowly pouring onto 1 to 3 uniforms the specified volume of specific stock as shown in the table below, another man turns and squeezes the clothing to insure even distribution of the emulsion. The emulsion that is not absorbed must not be salvaged and used again. Uniforms should be dried as given in (a) above.

Formula	For stock emulsion: Amount of concentrate	For stock emulsion: Amount of water	Amount of stock emulsion per uniform	Number of uniforms
		Cotton uniforms		
M-1960	1 gallon	2 gallons	18 oz	21
	6 oz	12 oz	18 oz	1
Benzyl benzoate	1 gallon	3 gallons	16 oz (1 pint)	32
	4 oz	12 oz	16 oz "	1
		Wool uniforms		
M-1960	1 gallon	5 gallons	32 oz (1 qt)	24
	5 oz	27 oz	32 oz "	1
Benzyl benzoate	1 gallon	5 gallons	24 oz	32
	4 oz	20 oz	24 oz	1

(3) Precautions

(a) Treated uniforms are not to be worn until dry.

(b) Do not over-treat; use the amounts of material given.

(c) Untreated undershorts should be worn under treated uniforms.

(d) It is not advisable to dip uniforms serially in the stock emulsions, as the concentrations given above will not be maintained in the emulsions after several uniforms have been dipped.

(e) Uniforms should be clean before impregnation with any of these repellents. Before reimpregnation, clothing should be thoroughly washed or dry cleaned.

b. PRESSURIZED SPRAY

Deet is the only repellent available as a pressurized spray. Clothing properly treated with an adequate amount of the spray provides as much protection as clothing treated by any other method. If less than 2 grams of active ingredient is applied per square foot it will be necessary to retreat at a shorter interval. The spray can be applied while the clothing is being worn.

The spray unit should be held 6 to 8 inches from the clothing and the spray applied with a slow sweeping motion. The operation is continued until the entire surface is slightly moistened; saturation is not necessary. For mosquitoes and biting flies extra liberal applications should be made where the most bites occur, such as across the shoulders and along the thighs. For ticks, chiggers, and fleas extra liberal applications are made along all openings of the clothing, such as the neckband, the fly and cuffs of the trousers, and the tops of the socks. The treatment of an entire uniform will usually require 3 to 4 minutes' spraying time.

c. UNFORMULATED REPELLENTS

Technical deet or a 75% solution of deet in alcohol can also be used to provide an effective all-purpose clothing treatment. M-2020 and M-250 may also be used, in an emergency, to treat clothing for protection against mosquitoes, biting flies and chiggers.

The best method of applying the repellents is to saturate the clothing with a solution or emulsion of the repellent. Use about 2 grams per square foot of cloth, or a total of 2½ ounces (5 tablespoonfuls) to a jacket (or shirt), trousers, and socks of medium size (total about 37 sq. ft.). Do not treat the underwear. Dissolve the repellent in enough dry-cleaning fluid to wet the garment thoroughly but not leave any excess, about 3 pints for an outfit of heavy cotton cloth. After all parts of the garment have been saturated with the solution, allow the cleaning fluid to evaporate. An emulsion can be made by mixing 2½ ounces (5 tablespoonfuls) of the repellent with 3 pints of water and 1/4 ounce (1½ teaspoonfuls) of an emulsifier or 1 ounce (2 tablespoonfuls) of soap. Many synthetic household detergents are not suitable for making emulsions, but most laundry soaps are satisfactory. Dissolve the emulsifier or soap in the water and add the repellent slowly while stirring vigorously. If large quantities of clothing are to be treated, a stock solution containing 90 per cent of the repellent and 10 per cent of emulsifier can be prepared, and added to water as needed, at the rate of 1/2 pint to 1 gallon. Saturate all parts of the garments with the emulsion, wring lightly, and DRY THOROUGHLY before wearing.

These repellents can also be sprayed or daubed on the clothing in areas where the bites occur, such as across the shoulders and along the thighs. A simple method is to shake the repellent into one hand, rub the hands together, and rub lightly on the clothing. They can also be applied to the clothing with a sprayer. If a compressed air sprayer that will deliver a very fine spray, such as a paint gun, is available the repellents may be applied at full strength. If only coarse sprays can be applied the repellents should be emulsified in soapy water or diluted with a volatile solvent. The important element is to treat the garments evenly at the rate of 2 grams of repellent per square foot.

4. RECOMMENDATIONS

Mixture M-1960 is recommended for the treatment of clothing when an all-purpose repellent is needed for protection against mosquitoes, fleas, ticks, and chiggers. Deet is also an excellent all-purpose clothing treatment; it is more effective than M-1960 against fleas, some mosquitoes and biting flies, but it is less effective against ticks and will not provide protection against chiggers after leaching with water.

Benzyl benzoate is recommended when the need for protection is limited to chiggers, as it is less expensive than M-1960 and withstands leaching by water. Deet is also highly effective against chiggers, but must be reapplied each time the clothing has been saturated with water.

Deet is recommended when fleas constitute the only problem. M-1960 is next in effectiveness and benzyl benzoate third.

Deet is also recommended when mosquitoes and biting flies are the only problem, although M-1960 is also highly effective. Benzyl benzoate is not suitable for this purpose.

When ticks are the only problem M-1960 is recommended. Deet is less effective than M-1960, but will nevertheless provide a high degree of protection through several days of wear. Benzyl benzoate is much less effective than deet.

In an emergency, when M-1960, deet, and benzyl benzoate are not available, M-2020 or M-250 may be used to provide some protection as clothing treatments. They are effective against mosquitoes and effective against chiggers unless the clothing has been saturated with water but only moderately effective against ticks.

Repellents should always be applied to dry clothing except when treated in a laundry. The treatment of wet clothing, as described in the section on methods of treatment, is recommended only as an alternative to no treatment at all. The impregnation of wet uniforms is difficult, and slight deviations from the methods recommended may result in underdosing, overdosing, or uneven distribution.

Clothing properly impregnated with M-1960, benzyl benzoate, and deet usually remains effective through normal periods of wear, and should be retreated when the clothing is washed. If the periods of wear are unusually long or severe in other ways it may be necessary to reapply deet between washings. This should not normally be necessary with M-1960 or benzyl benzoate, and overdoses of these materials caused by unnecessary retreatment without prior washing should be avoided.

When troops are going into areas where scrub typhus or other arthropod borne diseases are known to be present, clothing should be issued which has been treated with a repellent appropriate for conditions in such areas.

APPENDIX

The following qualitative test for the presence of M-1960 has been used in the field to establish that clothing has been treated. It does not, however, reveal the degree of impregnation or protection provided.

SPOT TEST FOR CLOTHING TREATMENT M-1960 ON CLOTH

Entomology Research Branch
Orlando, Florida

Reagent and Materials

1. The test reagent consists of 0.25 gram of ammonium thiocyanate, and 0.25 gram of sodium acid sulfate dissolved in 100 ml. of water, to which 1 ml. of a 1.0% aqueous solution of ferric chloride is added.

2. Acetone for moistening the cloth.

3. White, heavy grade, fine-textured qualitative filter paper. (Whatman No. 2 or equivalent).

4. Two dropper bottles

   (a) For acetone
   (b) For reagent

Procedure

A small portion (about 2 inches square) of the garment to be tested is wetted with acetone and then rubbed or sponged vigorously with the center portion of a piece of white filter paper. As soon as the acetone has evaporated one drop of the reagent is applied with a dropper to this portion of the paper. A blank test is made by placing a drop of the reagent on the outer part of the paper that was not wetted by the acetone. A distinct pink spot is formed with the extract from the impregnated garment. It is advisable to make the blank test since a slight pink color may develop even in the absence of the impregnant if the reagent is too concentrated.